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(54) **OPTICAL ELEMENT FOR UNIFORM LIGHTING**

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G02B 5/04 (2006.01)

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(58) **Field of Classification Search**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,821,804 B2 11/2004 Thibeault
7,352,011 B2* 4/2008 Smits H01L 33/54
257/100

(Continued)

FOREIGN PATENT DOCUMENTS

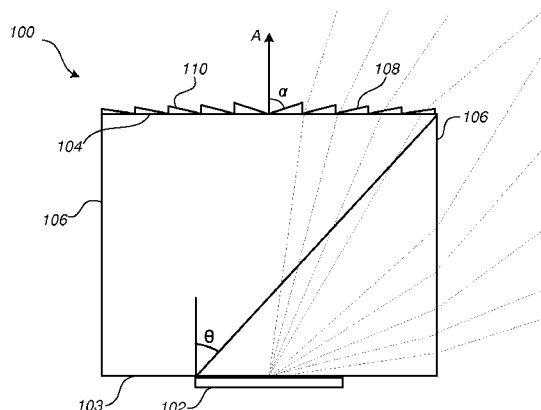
CN 101036501 A 1/2011
CN 201779526 U 3/2011
CN 102282416 A 12/2011

Primary Examiner — Peggy Neils

(57) **ABSTRACT**

There is provided an optical element for use with a LED wherein a base face is arranged to receive incoming light from the LED. The optical element comprises a top face having a pattern of optical structures which refract light away from an optical axis (A) of the optical element. Further the optical element comprises a plurality of side faces extending between the top face and the base face and arranged to refract light from the light towards the optical axis (A). the top face extends such that it covers a first angular range relative to the optical axis (A). The first angular range is an angular range outside which light emitted by the LED would be subject to total internal reflection at an imaginary extension of the top face.

14 Claims, 6 Drawing Sheets



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* cited by examiner

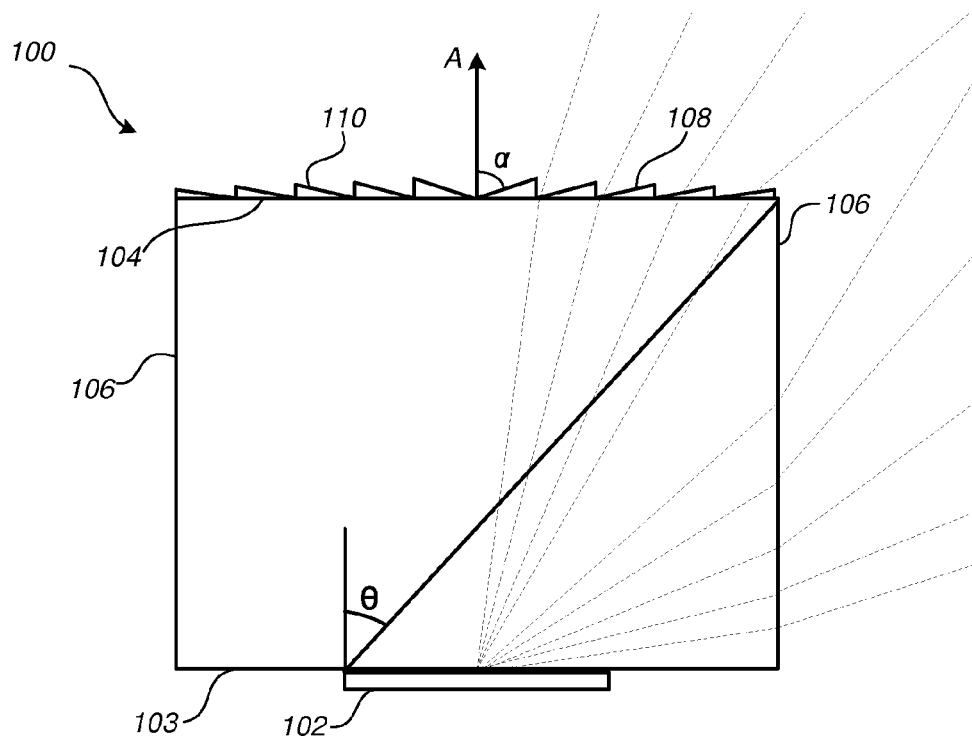


Fig. 1a

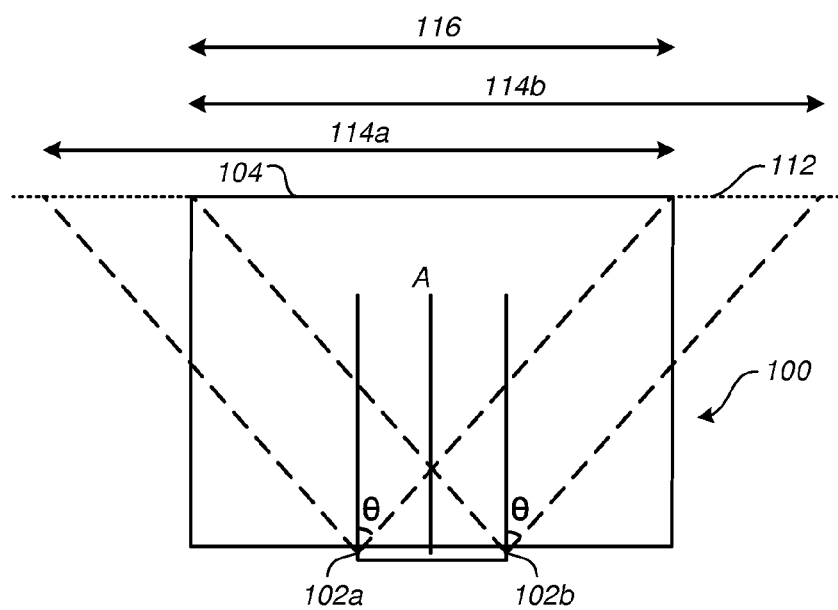
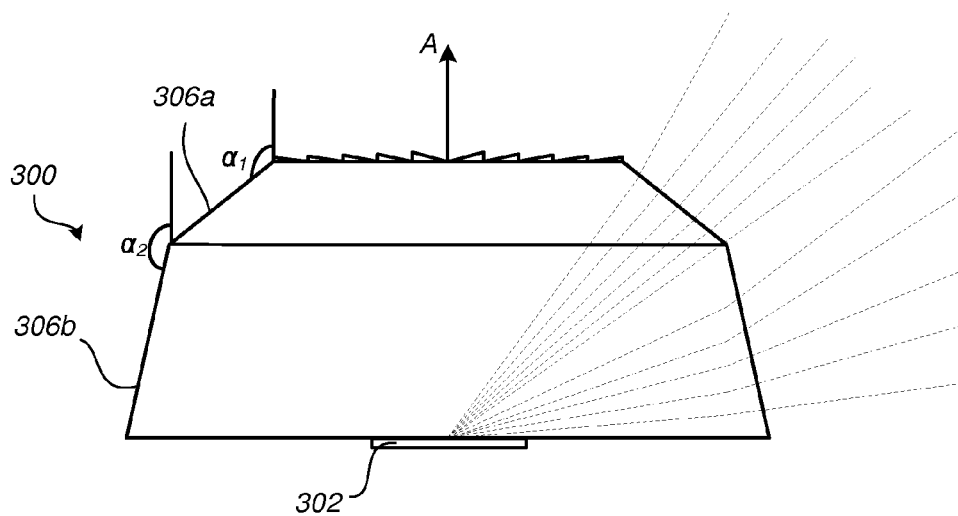
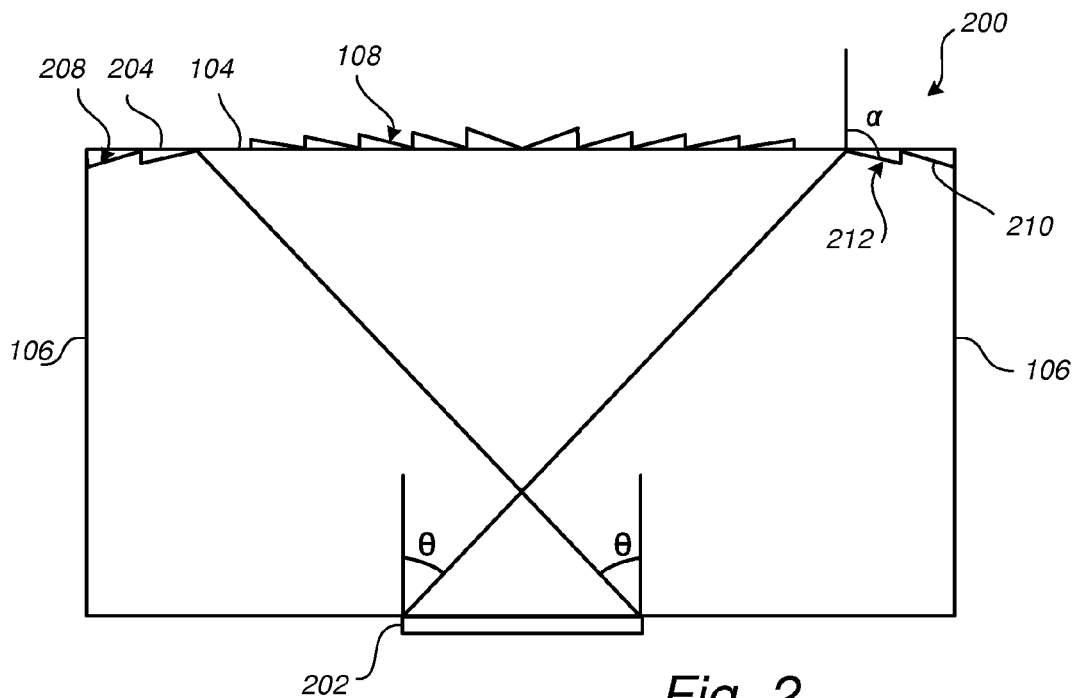


Fig. 1b



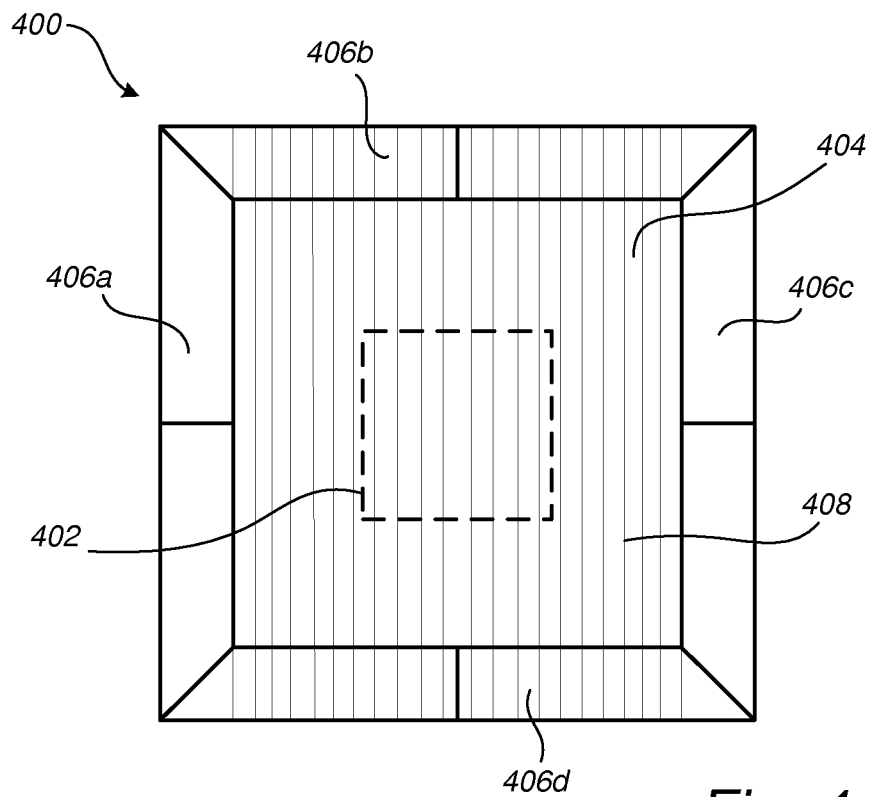


Fig. 4

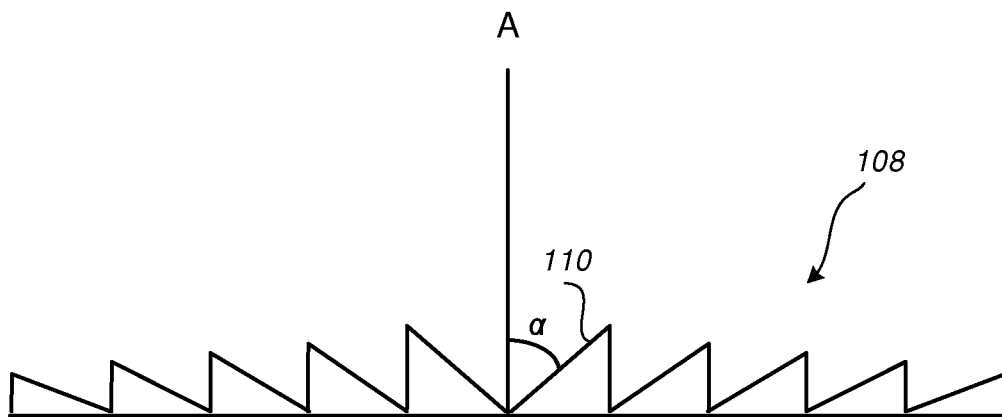


Fig. 5

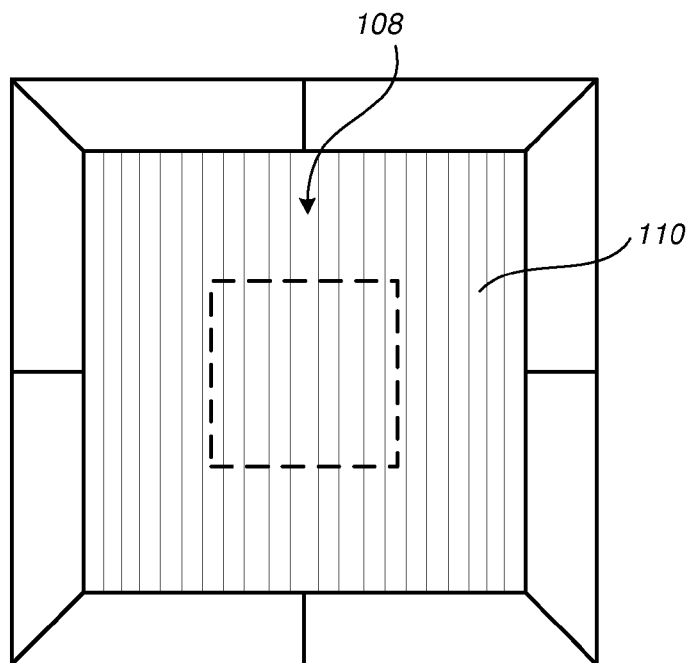


Fig. 6a

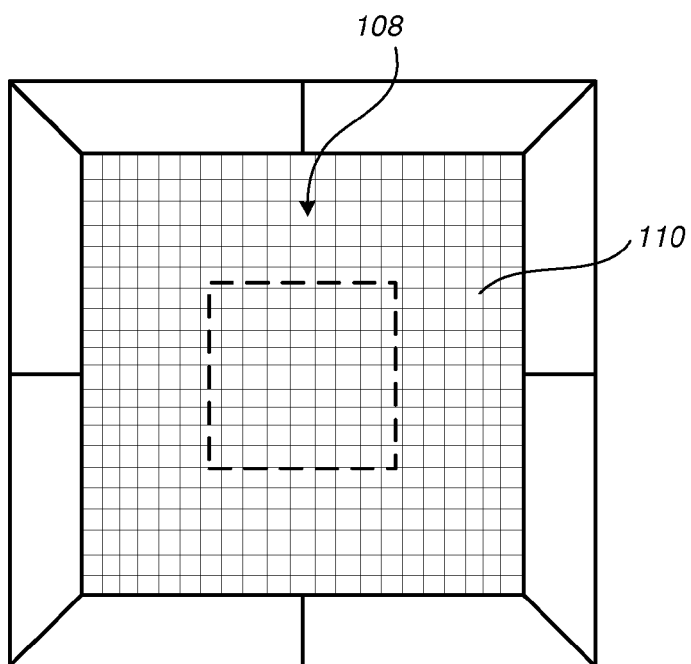


Fig. 6b

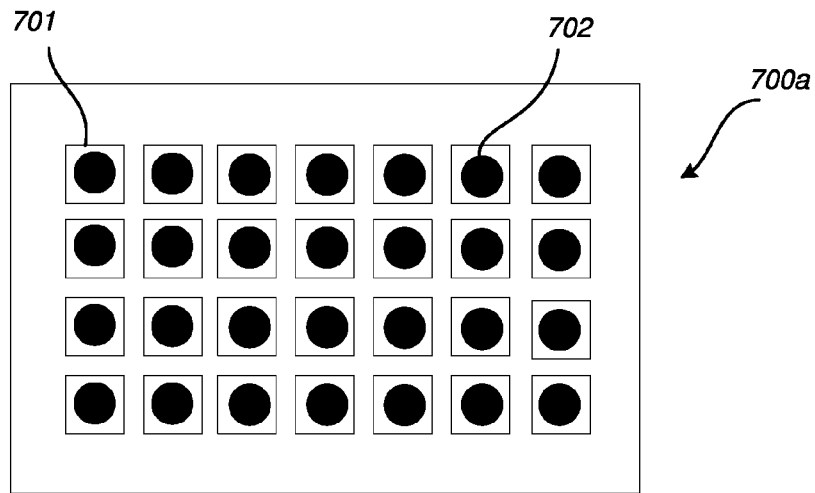


Fig. 7a

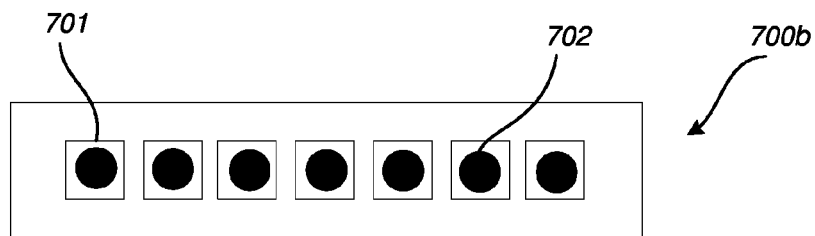


Fig. 7b

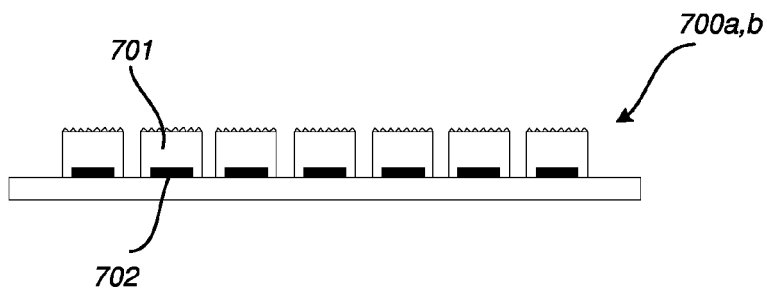
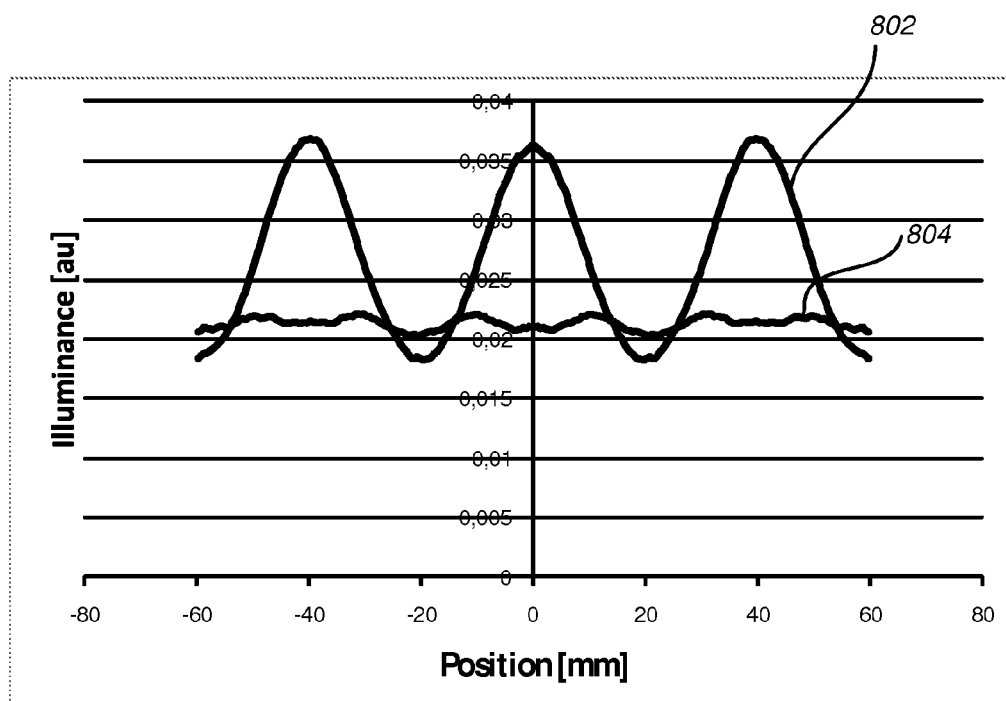


Fig. 7c

*Fig. 8*

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OPTICAL ELEMENT FOR UNIFORM LIGHTING

CROSS-REFERENCE TO PRIOR APPLICATIONS

This application is the U.S. National Phase application under 35 U.S.C. §371 of International Application No. PCT/IB2013/051131, filed on Feb. 12, 2013, which claims the benefit of U.S. Provisional Patent Application No. 61/599,453, filed on Feb. 16, 2012. These applications are hereby incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to the field of light emitting diodes (LED). In particular it relates to a refractive optical element for use with a LED.

BACKGROUND OF THE INVENTION

In recent years, the popularity of using LEDs in luminaires has increased. In order to obtain cost-efficient solutions, it is common to place several high power and/or medium power LEDs at a certain distance from each other in a luminaire. However, this has as a drawback that the luminaire will have a spotty appearance when in use, due to the irregular illumination pattern caused by the different LEDs.

Further, LEDs sometimes are used with colour converting layers, such as organic phosphor layers, in order to have an output light which is perceived as white by a user although blue LEDs are used. However, when having several LEDs in a luminaire, hot spots may be induced in the colour converting layer, which in the end leads to a reduced lifetime of the luminaire.

There have been attempts to overcome the above drawbacks by introducing diffuser elements in the luminaire in order to spread the light of the LEDs and thereby achieve a more uniform illumination pattern. However, these attempts suffer from reduced system efficiency and increased costs.

CN201779526 discloses a light source which comprises LED chips being fixed to a substrate. On top of each LED chip there is a thin light transmitting layer and on the side surfaces of the LED chip there are inclined structures which refract horizontally emergent light upwards. The disclosed LED light source is inter alia alleged to increase the radiating effect of the LEDs.

Although several attempts have been made to overcome the difficulties above, there is still room for improvements.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome or mitigate the above problems, and to provide an optical element for use with a LED which provides a more uniform illumination pattern in combination with low efficiency losses.

According to a first aspect of the invention, this and other objects are achieved by an optical element for use with a LED, comprising a base face arranged to receive incoming light from the LED, a top face having a normal extending in a direction from the base face to the top face and defining an optical axis, wherein the top face extends such that it covers a first angular range relative to the optical axis, outside of which first angular range light emitted by at least one point of the LED would be subject to total internal reflection at an

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imaginary extension of the top face, and wherein the top face comprises a first pattern of first optical structures which are arranged to refract light originating from the LED away from the optical axis; and a plurality of side faces extending between the base face and the top face and arranged to refract light originating from the LED towards the optical axis.

By the feature that light emitted by at least one point of the LED would be subject to total internal reflection (TIR) at an imaginary extension of the top face is meant that if the top face had extended any further, light emitted by at least one point of the LED would be subject to TIR at the top face. Thus, as further explained below, no TIR occurs within the first angular range.

By having a pattern of structures on the top face which refracts incident light away from the optical axis, and by having side faces arranged to refract incident light towards the optical axis, the incident light is spread out. Particularly, the first pattern of structures on the top face enhances a widening of the light output. As a result, a more uniform illumination pattern is achieved compared to the case that no optical element is used. This is particularly advantageous if several LEDs are arranged at a distance from each other in a light source, since the spotty appearance of the light source is reduced due to the spreading of the light.

Further, the optical element leads to very low efficiency losses. More specifically, energy losses may occur if total internal reflection takes place and the light emitted by the LED is directed back towards the LED where it may be absorbed. For example, such TIR could occur in the top face or the side faces of the optical element. However, with the present invention, the dimensions of the top face are chosen such that TIR cannot take place in the top face. More specifically, the top face extends such that it only covers a first angular range outside of which light emitted by at least one point of the LED would be subject to TIR. Hence no TIR takes place at the top face and the efficiency losses are thereby reduced. Moreover, since the side faces refract rays towards the optical axis, the risk that the rays will hit any obstruction such as adjacent LEDs or side walls before reaching a target surface is reduced. In this way, the side faces also contribute to the reduction of efficiency losses.

A further advantage is that the optical elements easily may be incorporated into LED packages during the manufacture of the LEDs and hence increase the functionality of a LED arrangement without increasing the cost significantly.

The plurality of side faces may further be inclined with respect to the optical axis. In this way, the TIR taking place at the side faces may be reduced. For example, the angle of inclination may be chosen such that TIR is avoided in the side faces, wherein the angle with respect to the optical axis is not equal to 90 degrees, for example larger than 90 degrees. If TIR takes place at the side faces, light emitted by the LED is spread out above the LED in mainly one direction. As an alternative to the side faces being straight and inclined with respect to the optical axis, the side faces may have a curved shape.

At least one of the plurality of side faces may comprise a first portion and a second portion having different inclinations or angles with respect to the optical axis. By tuning the inclinations or angles of the first portion and the second portion with respect to the optical axis, better control of the direction of the emitted light is achieved. As a result, the spotty appearance of a light source comprising several LEDs may be reduced further. In one embodiment, the number of portions of a side face having different inclinations is larger than two. The number of portions having different inclina-

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tions may be the same for all side faces or may be different for different side faces. For example, one side face may have two portions with different inclinations and another side face may have three portions with different inclinations.

In one embodiment, all side faces have the same inclination or angle with respect to the optical axis. This may be advantageous in that a symmetrical illumination pattern may be achieved. Similarly, all side faces may have the same dimensions. Having a symmetrical geometry of the optical element is advantageous in several aspects. For example, symmetrical optical elements are advantageous in that they are less sensitive to the orientation of the optical elements than non-symmetrical optical elements. This simplifies post-processing such as installation of the optical elements since a user does not have to consider the orientation of the optical element during installation. Symmetrical optical elements may also be advantageous from a manufacturing point of view depending on what type of manufacturing process is used. The first pattern of the top face may extend to at least one of the plurality of side faces. For example, the pattern of structures may extend to two of the side faces or to all of the side faces. This is advantageous in that a better spread of light in the side directions of the optical element, that is the directions perpendicular to the optical axis, may be achieved.

The optical element may comprise an extension of the top face which extends such that it exclusively covers a second angular range extending outwardly of the first angular range. The extension of the top face comprises a second pattern comprising second optical structures having top surfaces which are oriented to form an angle larger than 90 degrees relative to the optical axis. If the extension of the top face would not have any second pattern of second optical structures, TIR would occur in the extension of the top face. However, by including a second pattern of second optical structures having top surfaces which are oriented to form an angle larger than 90 degrees relative to the optical axis, the light output from the extension of the top face can be controlled such that the occurrence of TIR is reduced. As a consequence, the second pattern of structures provides for an increased collimation of the light output. However, as the occurrence of TIR is reduced, the second pattern increases the efficiency as light is not redirected towards the LED by which it may be absorbed. The embodiment with an extended top face may be particularly useful if the physical dimensions of the top face cannot, for example for design and/or construction reasons, be restricted to the angular range where TIR does not take place.

The first optical structures of the top face may each have a top surface which is oriented to form an angle being smaller than 90° with respect to the optical axis, wherein the angle increases as the distance to the centre of the top face increases. For example, the first optical structures may be saw-tooth shaped in cross-section. In this way, the refractive power of the structures on the top face is higher in the middle of the top face, where the intensity of incident light is relatively high, compared to at the edges, where the light intensity is lower.

The first optical structures may be arranged in a one-dimensional pattern. For example, the pattern may comprise ridge-shaped structures being arranged adjacent to each other. In this way, the light is spread in one direction. This may be particularly advantageous if the optical element is used in a light source with a one-dimensional array of LEDs. Alternatively, the first optical structures may be arranged in a two-dimensional pattern. If so, the light is spread in two

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directions. This may be particularly advantageous if the optical element is used in a light source with a two-dimensional array of LEDs.

According to a second aspect of the invention, this and other objects are achieved by a light emitting device comprising an optical element according to the first aspect being formed integrally with a LED.

According to a third aspect of the invention, this and other objects are achieved by a LED arrangement comprising a LED, and an optical element according to the first aspect, the optical element being associated with the LED.

The LED arrangement may further comprise a plurality of LEDs and a plurality of optical elements according to the first aspect, each of the plurality of LEDs being associated with one of the plurality of optical elements. The plurality of LEDs and their associated plurality of optical elements may be arranged in a one-dimensional array. Alternatively, the plurality of LEDs and their associated plurality of optical elements may be arranged in a two-dimensional array.

The advantages of the first aspect generally apply to the second and third aspects. It is noted that the invention relates to all possible combinations of features recited in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

This and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing embodiment(s) of the invention.

FIGS. 1a-b and FIGS. 2-3 are side views of an optical element used together with a LED according to embodiments.

FIG. 4 is a top view of an optical element used together with a LED according to embodiments.

FIG. 5 is a cross-sectional view of structures on a top face of the optical element according to embodiments.

FIGS. 6a-b are top views of an optical element used together with a LED according to embodiments.

FIGS. 7a-b illustrate top views of arrangements of LEDs and optical elements according to embodiments.

FIG. 7c is a side view of the arrangements of FIGS. 7a-b.

FIG. 8 illustrates the illuminance distribution of a linear LED arrangement. As illustrated in the figures, the sizes of layers and regions are exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of embodiments of the present invention. Like reference numerals refer to like elements throughout.

DETAILED DESCRIPTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person.

FIG. 1a illustrates an optical element 100 which is arranged to be used together with a LED 102. The size of the emitting area of the illustrated LED 102 represents the size of the emitting area of the LED die. The optical element 100 may be placed on top of the LED 102. The optical element 100 may either be an element which is separate from the LED 102 or may be formed integrally with the LED 102.

The optical element 100 is a solid transparent structure which has a base face 103, a top face 104 and a plurality of side faces 106. The top face 104 is parallel to the base face

103 and is located at a distance from the base face **103**. The side faces **106** extend between the base face **103** and the top face **104**. The LED **102** is arranged at the base face **103** such that light emitted by the LED **102** enters the optical element **100** at the base face **103**. The number of side faces **106** may vary. Preferably, however, the optical element **100** comprises four side faces **106**. The geometrical dimensions of the side faces **106** may be different or the same. The optical element **100** further has an optical axis A which is defined by a normal of the top face **104**, which is essentially perpendicular to the top face **104** and the base face **103** and extends in a direction from the base face **103** to the top face **104**.

The top face **104** has a first pattern **108** on its upper side facing away from the LED **102**. As illustrated, the first pattern **108** comprises first optical structures **110** which are arranged to refract light originating from the LED **102** away from the optical axis A. This may for example be achieved by the first optical structures **110** having top facets which are oriented to form an angle \bullet being smaller than 90° with respect to the optical axis A. In the illustrated embodiment, the angle \bullet for adjacent first optical structures **110** increases as the distance to the centre of the top face **104** increases. In this way, the refractive power of the first optical structures **110** is largest in the middle of the top face **104** and decreases towards the edges of the top face **104**.

Similarly, the side faces **106** are arranged to refract light originating from the LED **102** towards the optical axis A. In this way a uniform illumination pattern may be obtained, in particular if several LEDs are arranged in an array. Further, as the light is directed towards the optical axis A, the emitted light is less likely to hit any obstruction outside of the optical element prior to reaching its target, such as an adjacent LED. Hence, the efficiency is thereby improved. The side faces **106** may for example be straight and may for example form an angle with respect to the optical axis A that is not equal to 90 degrees. The angle of the side faces **106** with respect to the optical axis A may be chosen such that TIR is avoided at the side faces **106**. Alternatively, one or more of the side faces **106** may be curved. As is further explained below, one or more of the side faces **106** may be multifaceted.

The geometrical size of the top face **104** in a direction perpendicular to the optical axis A is chosen such that TIR is avoided at the top face **104**. Since TIR is avoided the efficiency losses due to the optical element **100** are very small. In more detail, the size of the top face **104** is chosen such that if the top face **104** had extended any further in a direction perpendicular to the optical axis A, light emitted by at least one point of the LED **102** would have been subject to TIR at the top face **104**.

This is further illustrated in FIG. 1b which shows the LED **102** and the optical element **100** of FIG. 1 as well as an imaginary extension **112** of the top face. The emitting area of the LED **102** has a geometrical extent. As a consequence, each point of the LED **102**, such as the illustrated points **102a-b**, may emit light. Point **102a** is the leftmost point of the LED **102** and point **102c** is the rightmost point of the LED **102**. For each of the points of the LED **102**, such as points **102a-b**, an associated angular range defined by an angle \bullet relative to the optical axis A is defined. Here, angular ranges **114a-b** are associated with the points **102a-b**, respectively. The angle \bullet is associated with an angle above which TIR of light emitted by the LED **102** would occur in the imaginary extension **112** of the top face **104**. In other words, had the top face **104** extended any further, TIR would take place in the top face **104** for light emitted by the LED **102** above the angle \bullet . Hence, light emitted by any point of the LED such as one of points **102a-b** at an angle larger than the

angle \bullet would be subject to TIR as it reaches the imaginary extension **112** of the top face **104**. The angle \bullet may easily be calculated by the laws of refraction once the refractive index of the optical element **100** is known.

In order to avoid TIR at the top face **104**, the top face **104** should not extend outside of any of the angular ranges which may be associated with any point of the LED **102**. This is achieved by the top face **104** covering a first angular range **116** relative to the optical axis A which corresponds to the intersection of the angular ranges which may be defined for any of the points of the LED **102**. In particular it may be seen to correspond to the intersection of the angular ranges **114a** and **114b** which may be defined for the peripheral points **102a** and **102b** of the LED **102**. In this way, the top face **104** does not extend outside of any of the angular ranges **114a-b** where TIR takes place and hence TIR in the top face **104** is avoided. Differently stated, outside of the first angular range **116**, that is, at the imaginary extension **112**, light emitted by at least one point of the LED **102** is subject to TIR.

FIG. 2 illustrates an optical element **200** which is used together with a LED **202**. This embodiment differs from the embodiment described with reference to FIG. 1a in that it further comprises an (non-imaginary) extension **204** of the top face **104**. The extension **204** of the top face **104** extends in a direction perpendicular to the optical axis A such that it exclusively covers a second angular range extending outwardly of the first angular range **116** disclosed with respect to FIG. 1b. In other words, the first and second angular ranges are non-overlapping. Since the extension **204** covers a second angular range extending outwardly of the first angular range, TIR may occur at the extension **204** if no further means are taken. In order to avoid TIR in the extension **204** of the top face, the extension **204** comprises a second pattern **208**. The second pattern **208** comprises a second optical structure **210** which is arranged to refract light towards the optical axis A. For example, this may be achieved by a second optical structure **210** having facets **212** which are oriented such that they define an angle \bullet larger than 90° with respect to the optical axis A. For example, the angle \bullet of adjacent second optical structures **210** may increase as the distance to the edges of the extension **204** of the top face decreases. The embodiment of FIG. 2 may be particularly useful when the top face cannot be given an arbitrary size for practical reasons but is restricted to certain conditions. For example, this embodiment may be used if the top face **104** is restricted to a size being equal to the size of the emitting area of the LED **102**.

Between the pattern **108** of the first optical structures of the top face **104** and the second pattern **208** of second optical structures of the extension **204** of the top face, there may be a portion of the top face **104** where there are no optical structures. That portion may be seen to correspond to optical structures having an angle \bullet equal to 90° with respect to the optical axis A.

FIG. 3 illustrates an optical element **300** to be used with a LED **302**. The optical element **300** has a top face **304** and side faces wherein at least one of the side faces comprises a first portion **306a** being located closest to the top face **304** and a second portion **306b**. In the illustrated embodiment, all side faces comprise a first and a second portion **306a** and **306b**. However, in general, different side faces may comprise different number of portions. The illustrated first portion **306a** and the second portion **306b** are essentially straight. For example, the first portion **306a** and the second portion **306b** may be in the form planar surfaces. The first portion and the second portion **306a** and **306b** may have different inclinations with respect to the optical axis A.

Particularly, the first portion **306a** may have a first inclination defined by angle \bullet_1 with respect to the optical axis A, and the second portion **306b** may have a second inclination defined by angle \bullet_2 with respect to the optical axis A, where $\bullet_2 > \bullet_1 > 90^\circ$. For example, the inclination \bullet_1 of the first portion **306a** may be chosen such that essentially no refraction of light occurs as light emitted by the LED **302** passes through the first portion **306a**. At the same time, the inclination \bullet_2 of the second portion **306b** may be chosen such that light emitted by the LED **302** is refracted towards the optical axis A. By varying the angles or inclinations and sizes of the different portions **306a-b** of the side faces, the direction of the emitted light can be controlled.

In an alternative embodiment, the first portion **306a** is curved, such that it has a shape of a second or higher order degree curve or surface. Alternatively, it may be in the form B-splines or rational Bezier curves. Alternatively, the cross-section of the first portion **306a** may be in the shape of a segment of a circle. In this way, the first portion **306a** may be designed to have a shape by which light emitted by the LED **302** impinges essentially perpendicularly on the first portion **306a** such that essentially no refraction of the light is obtained.

FIG. 4 is a top view of an optical element **400** having a top face **404** with a first pattern **408** and side faces **406a-d**. The optical element **400** is used with a LED **402**. In this embodiment, the first pattern **408** further extends to at least one of the plurality of side faces **406a-d**. Here, the pattern extends to two side faces, namely the oppositely arranged side faces **406b** and **406d**. However, the pattern may also extend to all of the side faces **406a-d**. In case the optical element **400** has side faces **406a-d** being divided into different portions having different angles or inclinations as discussed above with respect to FIG. 3, the pattern **408** may extend to only one of the portions, to some of the portions, or to all portions. By having a first pattern of first optical structures also on the side faces **406**, light emitted by the LED **402** is further refracted and spread out. In this way, the illumination distribution resulting from the LED **402** when used with the optical element **400** may be further improved. In particular, the illumination in a direction perpendicular to the optical axis may be improved.

FIG. 5 illustrates an example of the first pattern **108** of first optical structures **110** of the top face. In principle, the first pattern **108** of first optical structures **110** may have any shape as long as it serves to refract light emitted by the LED away from the optical axis A. Here, the first pattern **108** comprises a plurality of adjacent first optical structures **110** having a saw tooth shaped cross-section. The saw tooth shaped first optical structures **110** have a top surface which is oriented to form an angle \bullet being smaller than 90° with respect to the optical axis A. The angle \bullet increases as the distance to the centre of the top face **104** increases. In this way, the refractive power of the first pattern **108** decreases towards to the edges of the top face.

In case the optical element comprises a second pattern, such as pattern **208** of FIG. 2, the second optical structures of the second pattern may also have a saw-tooth shape in cross-section.

FIGS. 6a-b are examples of how the first pattern of first optical structures may be arranged on the top face of the optical element. In FIG. 6a the first optical structures **110** are arranged in a one-dimensional pattern. For example, the first optical structures **110** may be in the form of ridges being arranged adjacent to each other to form the resulting pattern **108**. The ridges may for example have saw-tooth shaped cross-sections as described with respect to FIG. 4. By

arranging the first optical structures **110** in a one-dimensional pattern, spreading of the light in one direction is achieved.

In FIG. 6b the first optical structures **110** are arranged in a two-dimensional pattern. For example, the individual first optical structures **110** forming the first pattern **108** may be in the form of half-pyramids being arranged adjacent to each other. Other alternatives are quarter spheres or ellipsoids. By arranging the first optical structures **110** in a two-dimensional pattern, the light is spread in two directions.

The examples disclosed above also apply to the second pattern **208** disclosed with respect to FIG. 2.

FIGS. 7a-c illustrate examples of LED arrangements comprising optical elements according to the embodiments described above. The LEDs may for example be phosphor coated LEDs emitting white light or LEDs emitting blue light with a remote phosphor. FIG. 7a illustrates a rectangular light source comprising a plurality of LEDs **702** and a plurality of optical elements **701**. The LEDs **702** are arranged in a rectangular array. Similarly, FIG. 7b illustrates a linear light source **700b** comprising a plurality of LEDs and a plurality of optical elements **701**. The LEDs **702** are arranged in a linear array. Each LED **702** of the rectangular array and the linear array is associated with one of the plurality of optical elements **701** being placed on top of the LED or formed integrally with it as illustrated in FIG. 7c.

By associating each LED **702** with an optical element **701**, the illumination distribution of the resulting light source **700a** or **700b** is improved, meaning that the illumination distribution is more uniform compared to the case where no optical elements **701** are used. FIG. 8 illustrates the illumination distribution of a linear light source having three LEDs arranged at a distance of 50 mm from each other. The illumination plane is at a distance of 20 mm from the LEDs. Curve **802** represents the illuminance distribution when no optical elements are present and curve **804** represents the illuminance distribution with optical elements present. From FIG. 8 it clearly follows that the illuminance distribution is more uniform when optical elements are used. In practice this means that the spotty appearance of the light source is reduced, and that in the case of remote phosphor applications the lifetime is increased due to the reduction of hot spots in the phosphor layer.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. For example, the side faces may comprise more than two portions having different shapes. Further, there are many alternatives regarding the shape of the first optical structures of the top face.

Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

The invention claimed is:

1. An optical element for use with a LED, comprising:
 - a base face arranged to receive incoming light from the LED,
 - a top face having a normal extending in a direction from the base face (**103**) to the top face and defining an optical axis,

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wherein the top face extends such that it covers a first angular range relative to the optical axis, outside of which first angular range light emitted by at least one point of the LED would be subject to total internal reflection at an imaginary extension of the top face, and

wherein the top face comprises a first pattern of first optical structures which are arranged to refract light originating from the LED away from the optical axis; a plurality of side faces extending between the base face and the top face, the plurality of side faces being arranged to refract light originating from the LED towards the optical axis; and

wherein an extension of the top face extending such that it exclusively covers a second angular range extending outwardly of said first angular range, wherein the extension of the top face comprises a second pattern comprising second optical structures having top surfaces which are oriented to form an angle larger than 90 degrees relative to the optical axis (A).

2. The optical element according to claim 1, wherein the plurality of side faces are inclined with respect to the optical axis.

3. The optical element according to claim 2, wherein at least one of the plurality of side faces comprises a first portion and a second portion having different inclinations with respect to the optical axis.

4. The optical element according to claim 2, wherein all side faces have the same inclination with respect to the optical axis.

5. The optical element according to claim 1, wherein all side faces have the same geometrical dimensions.

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6. The optical element according to claim 1, wherein the first pattern of the top face extends to at least one of the plurality of side faces.

7. The optical element according to claim 1, wherein the first optical structures each have a top surface which is oriented to form an angle being smaller than 90 degrees with respect to the optical axis and wherein the angle increases as the distance to the centre of the top face increases.

8. The optical element according to claim 7, wherein the first optical structures are saw-tooth shaped in cross-section.

9. The optical element according to claim 1, wherein the first optical structures are arranged in a one-dimensional pattern.

10. The optical element according to claim 1, wherein the first optical structures are arranged in a two-dimensional pattern.

11. A light emitting device comprising an optical element according to claim 1 formed integrally with an LED.

12. A LED arrangement comprising

a LED, and

an optical element according to claim 1, the optical element being associated with the LED.

13. The LED arrangement according to claim 12, comprising a plurality of LEDs each being associated with an optical element, wherein the plurality of LEDs are arranged in a one-dimensional array.

14. The LED arrangement according to claim 12, comprising a plurality of LEDs each being associated with an optical element, wherein the plurality of LEDs are arranged in a two-dimensional array.

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